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ASSIGNMENT OF FREQUENCIES TO SIGNALLING CIRCUITS IN THE AUTOMATION
OF TOLL CIRCUITS

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The results of the study of the effect of voice-frequency currents on the operation of receiving equipment tuned to different frequencies in the voice band are discussed briefly. On the basis of the results which have been obtained, the use of a single-frequency dialling and calling system with a frequency in the 2,100-2,300 cycle range is recommended.

The transmission of control signals over long toll circuits is one of the most difficult problems to be solved in the automation of long-distance communications. The complexity of the problem is due to the attenuation of the signals and the appearance of a number of distorting and interfering factors. The only correct solution of this problem appears to be the utilization of voice-frequency signals, which will make it possible to transmit signals and control switching operations over the same distance as that over which telephone communications can be carried on.

However this at first glance simple solution in practice presents a number of difficulties. The utilization of one and the same channel for the transmission of both control signals and message currents may lead to the appearance of false signals which can interfere with proper switching operations or disrupt established connections. Hence the voice-frequency dialling equipment must be protected from the generation of false signals. The possibility of shielding the equipment from voice-frequency interference by a number of methods has led to a great variety of signal-transmission systems.

Depending on transmission conditions the control signals utilized with automatic and semiautomatic toll circuits can be divided into 2 classes: (1) signals which are transmitted during the establishment of a connection, and (2) signals transmitted after the connection has been established. To the first group belong the dial-tone, dialling, and answering signals, to the second -- the supervisory, disconnect, and other signals. In as much as during the establishment of the connection voice-frequency currents can enter the circuit only from the originating end (the calling subscriber or toll switchboard) the appearance of false signals can easily be prevented by disconnecting the message circuit in the transmitting equipment. Hence the difficulties in selecting the proper method of eliminating false signals appear mainly after the connection has been established, when the voice-frequency receiving equipment is connected in parallel with the talking circuit during the entire duration of the conversation between subscribers.

In the case of manual switching conditions during the transmission of the supervisory and disconnect signal are identical with those prevailing during voice-frequency dialling. In developing a voice-frequency dialling system for such applications thought must again be given to the elimination of false signals. In as much as the power-level of the message currents is unevenly distributed over the voice-frequency band the appearance of false dial signals, as well as the appearance of false signals [noise] during

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automatic long-distance communications depends to a marked extent on the frequency selected.

In accordance with the recommendations of the MKKF issued in 1928, the 500/20 (500 cycles interrupted 20 times a second) system was chosen as the basis for toll communications. These recommendations are still in force. However in 1931 it was brought out that the 500/20 system gave no assurance whatever concerning the elimination of false signals in view of the fact that the combination of frequencies of 480, 500, and 520 cycles is encountered quite frequently in voice communication. It therefore became necessary to install retardation coils in the voice-frequency receivers in addition to the double selectivity, introducing a delay of 500-1,000 msec, as well as protective circuits which prevented the operation of the receiver when currents with frequencies other than the control frequency were received.

Side by side with the voice-frequency dialling system there appeared many other control-signal transmission systems for automatic toll circuits -- single-frequency systems using 500, 600, and 1,000 cycles, as well as multifrequency systems. Among the latter one finds the 4-frequency system (500, 600, 750, and 900 cycles) in which the signals are transmitted by means of various combinations of one, 2, 3, and 4 frequencies. All these systems failed to find wide application and were eclipsed by two-frequency systems using 600 and 750 cycles. In 1938 the 600-750 2-frequency system was recommended by the MKKF for automatic toll circuits, and hence most of the voice-frequency dialling equipment developed since that time uses these two frequencies in the control circuits.

The theory concerning the allocation of frequencies to signalling circuits on telephone transmission lines and all the experimental evidence until recently tended to support the superiority of 600-75- 2-frequency systems over single-frequency systems using frequencies of the same order of magnitude.

From the graph shown in Figure 1 it can be seen that when control frequencies of 600 and 750 cycles are used simultaneously the number of false operations of the receiving apparatus is considerably less than for single-frequency receivers tuned to either 600 or 750 cycles. However experience has shown that neither type 600-750 nor single-frequency systems can provide good protection against voice-frequency interference without the introduction of great retardations in the relay-switch banks. The 600-75- systems also have another shortcoming: the transmission of currents of 2 frequencies lying so close together requires additional measures for the elimination of interference effects caused by one of the frequencies in the receiver circuits tuned to the other. This leads to complications in receiver design and raises equipment costs.

Recent years have seen the introduction of systems utilizing frequencies in the upper voice-frequency band. To this group belong systems using the following frequencies: 1,600, 2,000, 3,000, 1,740-2,300, and 3,000-3,500 cycles. In addition, multifrequency coded-pulse dialling and other, noncode, control-signal transmission systems have been developed. The last group is used with single-frequency receivers which are permanently associated with the line. Multifrequency receivers serve a number of lines: they are connected to the line together with the register only during the making of the connection.

An analysis and comparison of existing signal transmission circuits shows that all have certain marked shortcomings, which make some other solution necessary. This leads to the utilization of some new, never-before utilized system of voice-frequency dialling with every new piece of long-

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haul toll equipment, and to a radically new solution of the question of control signal transmission in the organization of the automatic long-distance telephone system. Meanwhile voice-frequency calling systems are replaced with analogous voice-frequency dialling systems. As experience with the introduction of the semiautomatic long-distance telephone system has shown such a substitution is economically undesirable. New equipment produced by industry designed for installation on aerial and cable trunks must be such as to permit the installation of automatic or semiautomatic switching equipment without alterations and replacement of signalling and control equipment.

In as much as the questions of the transmission of long-distance dialling pulses and of voice-frequency calling on manual lines are closely related they must be attacked simultaneously.

In order to be able to select the economically most-suited universal voice-frequency dialling and calling system which will be equally suited for manual, semiautomatic, and automatic service we must first of all assign the proper frequency or frequencies to the currents to be utilized in the transmission of the pulses. This can ease to a marked degree the problem of the reduction of attenuation losses.

The TsNNIS in cooperation with the laboratory for the development of scientific problems of wire communications of the AN SSSR has undertaken an extensive testing program in order to determine the optimum frequency at which the effect of message currents on the operation of the receiving apparatus will be minimal. A large number of receivers were tested for false operation when tuned to various frequencies in the voice band. Voice-frequency telegraph equipment was utilized in the tests.

In order to record the false pulses each of the 18 receivers operating on an 80-100 cycles band width is connected in turn in parallel with the talking wires of the 4-wire circuit in the type B-12 equipment, as shown in Figure 2. In the figure BK is the balancing network, DT is a differential transformer, UU a level indicator, MZ a variable attenuator, Tr a transformer, R the receiver-operated relay, and RI the recording instrument. In order to eliminate any interference with the transmission of talking currents the equipment was connected to the line through a high ohmic-input amplifier. The amplified message signals enter the receiving section of the voice-frequency telegraph equipment through the variable attenuator MZ, which changes their level to the required value. The recorder RI is connected to the operating spring of the relay R. The number of false pulses of varying duration was recorded by means of counters.

The greatest threat to the proper operation of long-distance dialling equipment is posed by long-duration pulses (above 20 msec). Hence the retardation utilized in the registration of the pulses was set at 25, 50, 100, 200, and 400 msec. The sensitivity of the receivers remained constant during the tests. However, one can evaluate the effect of variations in sensitivity on the number of false impulses by comparing the results obtained for different amplifier gains applied to the signals fed into the receiver (figures 3 and 4).

The above set up was used to test the false-impulse operation of 18 receivers tuned to the following frequencies: 420, 540, 660, 780, 900, 1,020, 1,140, 1,260, 1,380, 1,500, 1,620, 1,740, 1,860, 1,980, 2,100, 2,220, 2,340, and 2,460 cycles. In addition to the investigation of the effect of message currents transmitted over actual telephone circuits tests were also undertaken with male and female voices recorded on magnetic tape (figures 5 and 6). Moreover, the simultaneous operation of 2 sets of receiving equipment by a combination of live and recorded signals was also investigated. The

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tests carried out with actual telephone circuits and with magnetic tape equipment gave concurring results concerning the dependence of the number of false operations on the frequency (frequencies) utilized, as well as concerning the introduction of delay-distortion in the switching circuits and the variation of the level of the signal fed into the receiving equipment.

A comparison of the results obtained led to a solution of the question of the necessity of utilizing Z-frequency systems to assure the protection of the receiving equipment against false operation, and also made it possible to establish the direction of future work on the development of transmission systems for voice-frequency pulses.

Figure 7 shows the curves giving the dependence of the number of false operations per hour on the delay-distortion introduced in the transmission of the pulses for both single and double-frequency systems. A comparison of the curves shows that when the 540-780 cycle system is used the number of false operations: (1) is considerably smaller than when the frequency 540 cycles is used alone; (2) not much smaller than that observed for 1,140 cycles; and (3) 17 times greater than that observed for 2,340 cycles. The utilization of a second frequency is more effective in the range 800 - 1,800 cycles than with frequencies under 800 and over 2,100 cycles. Thus the utilization of a combination of 1,140 and 1,620 cycles is much more effective than that of 540 and 730 cycles. The utilization of a combination of frequencies in the 2,100-2,300 cycle range does not lead to a marked lowering of the number of false operations relative to that achieved by the use of the higher frequency alone.

An analysis of the results obtained permits us to draw the following conclusions.

(1) With single-frequency systems an effective lowering of the number of false operations can be achieved by the utilization of frequencies over 2,000 cycles. When all other conditions are equal, the number of false operations recorded with receiving equipment tuned to a frequency in the 2,100-2,300 cycles range is 15-20 times smaller than that obtained with a combination of frequencies in the range below 800 cycles, for the power of the talking signals is maximal in that range (Figure 8).

(2) When a combination of frequencies in the 800-1,800 cycles range is used the number of false operations is smaller than that observed with a combination in the range below 800 cycles. It follows that the utilization of a 1,200-1,600 cycle frequency-combination in place of the presently utilized 600-750 cycle combination in semiautomatic narrow-band (dialling and other equipment) toll circuits would be more effective.

(3) The utilization of a combination of frequencies in the 2,100-2,300 cycle band cannot be recommended in view of the fact that the introduction of a second frequency in that range does not lead to a significant lowering of the number of false operations.

(4) The utilization of a single frequency above 2,400 cycles makes it impossible to use the same pulse transmission system in new equipment installed on existing lines, in low-frequency circuits, and in the development of automatic toll circuits using loading coils.

On the basis of what has been said we can conclude that the 600-750 and 500/20 pulse transmission systems recommended by the MKKF do not assure the proper protection of the receiving equipment from the effect of talking currents. In as much as existing systems of older design will remain in operation for quite some time to come a combination of currents in the 2,100-2,300

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cycle range must be used for the transmission of control signals in the organization of an integrated transmission system. The use of a single frequency in the 2,100-2,300 cycle range improves the protection of the receiving equipment against interference from the talking currents relative to that achieved with older systems. It can be used on the circuits of all existing manual and automatic toll systems.

The selection of a single-frequency system instead of one using two frequencies also facilitates the solution of the question concerning the reduction of distortion in the transmission of the signals. In practice it is impossible to construct a 2-frequency receiver having absolutely equal transmission bands with frequencies of both 600 and 750 cycles, and hence to obtain equal steady-state propagation times. As a result 2-frequency signals are always distorted to a greater extent than single-frequency signals.

The development of an integrated system for the transmission of control signals over the composited circuits of all existing systems makes possible the most economic solution of questions connected with the transmission of signals in both manual and automatic toll systems. The utilization of standard equipment also facilitates the organization of through-transmission as well as the selection of alternate connections.

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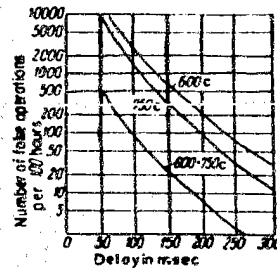


Figure 1. Dependence of the number of false operations on the false operations on the delay in the relay racks when one or 2 frequencies are utilized.

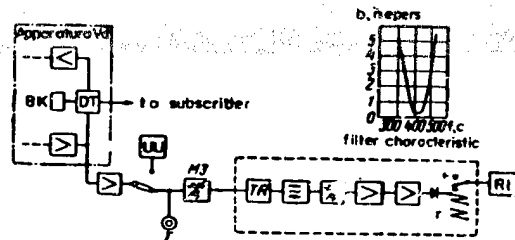


Figure 2. Arrangement used for the recording of false operations produced by the message currents in the circuit.

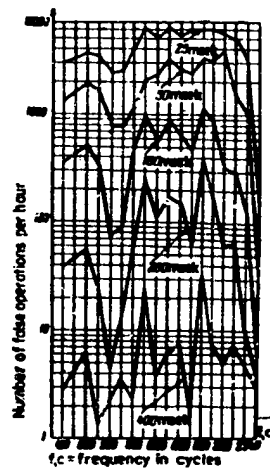


Figure 3. Dependence of the number of false operations on the tuning frequency of the receiver for a 0.5 neper message current level.

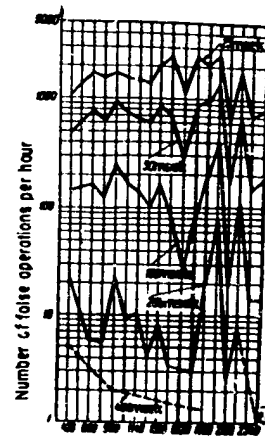


Figure 4. Dependence of the number of false operations on the tuning frequency of the receiver for a -0.5 neper message current level.

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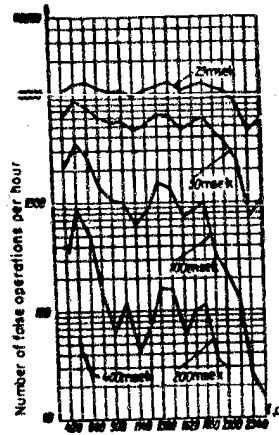


Figure 5. Dependence of the number of false operations on the tuning frequency of the receiver for recorded male and female speech signals and a message current level of 0.5 neper.

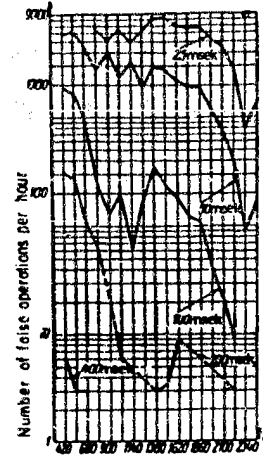


Figure 6. Dependence of the number of false operations on the tuning frequency of the receiver for recorded male and female speech with a message current level of -0.5 neper.

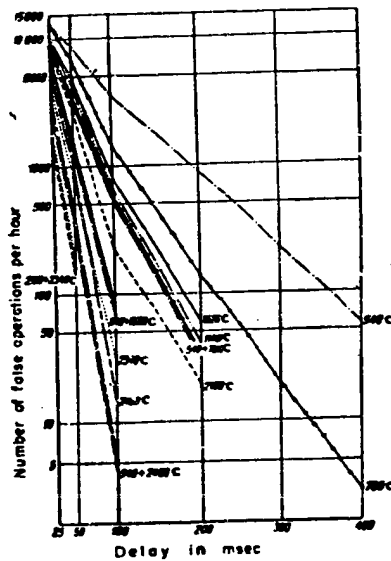


Figure 7. Dependence of the number of false operations on the transmission delay with single and 2-frequency operation (recorded male and female speech, 0.5 neper transmission level).

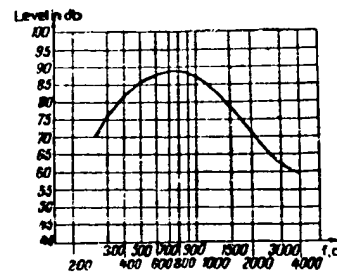


Figure 8. Dependence of the mean level of Russian speech on the frequency of the talking current.

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